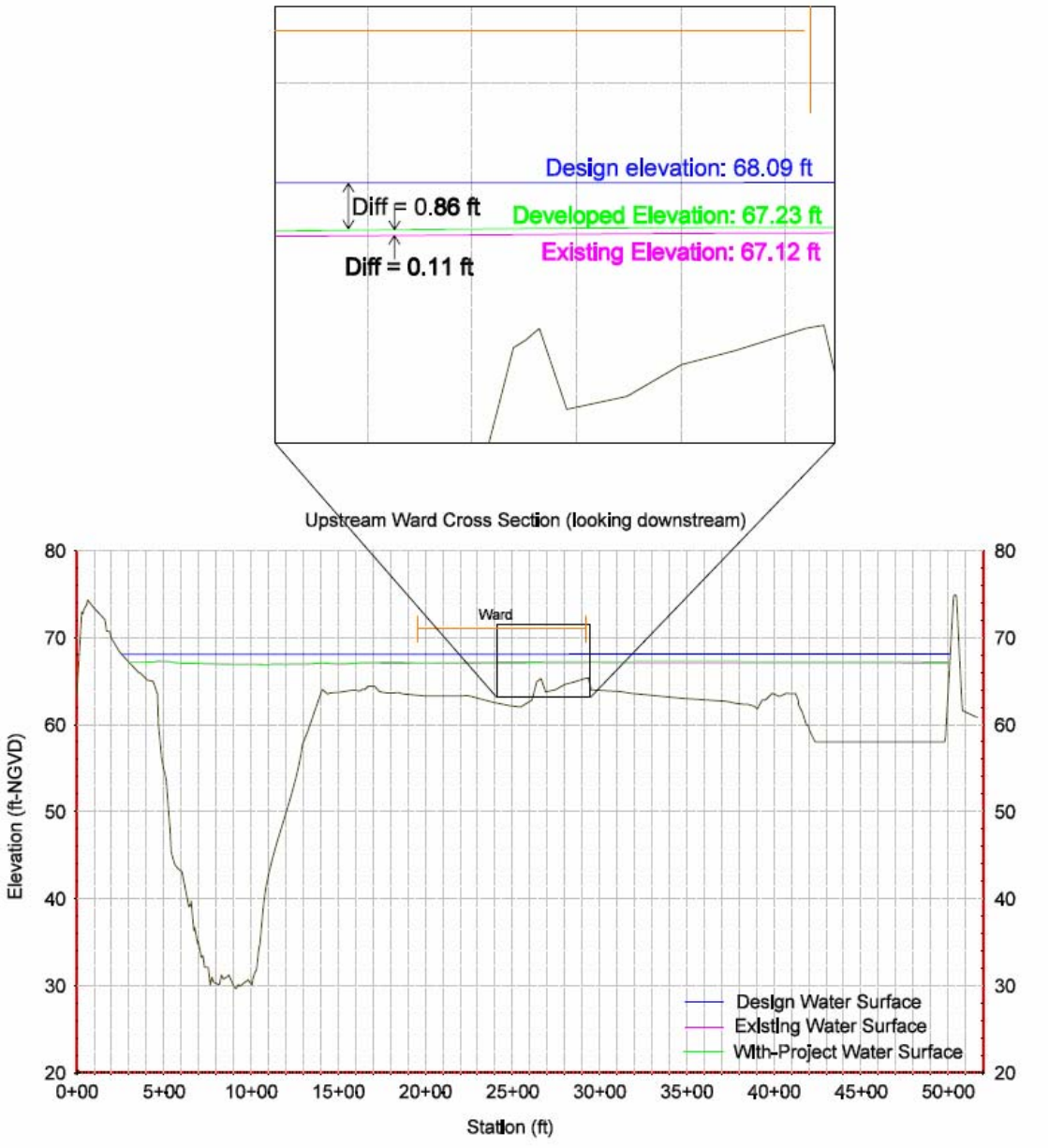


Figure 10: Modeled water surface elevation at cross-section taken along upstream portion of Ward Tract. The gray curve shows the ground surface, i.e. levees and river-bottom. The cross section looks downstream; the left levee is on the east, and the right levee is on the west. (Ayres Associates)

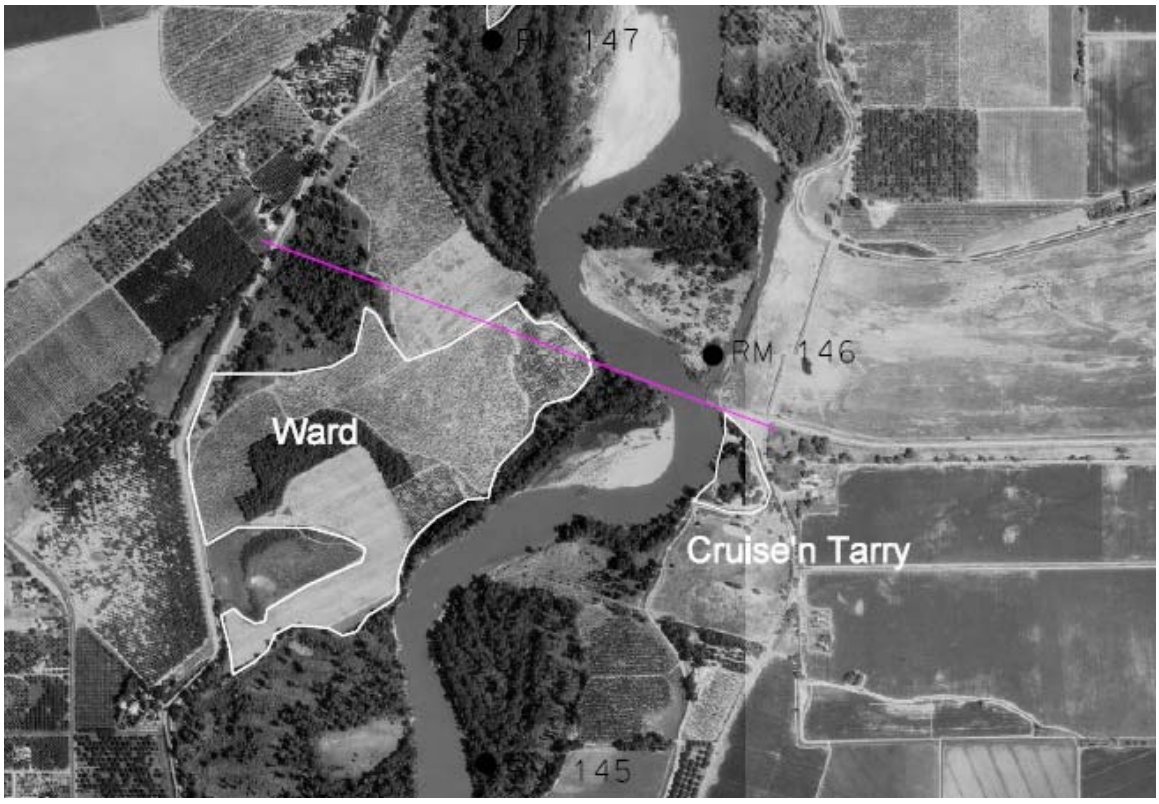


Figure 11: Map Key illustrating location of cross section displayed in previous figure (Ayres Associates)

Interpretation

- Model results indicate that the proposed restoration project at Ward Tract would lead to very little, and very localized rise in water surface elevation. The localized rise in water surface elevation that slightly exceeds 0.10 ft would be confined to the yellow triangular area shown in **Figure 9.** The maximum increase in water surface elevation was modeled to be 0.15 ft. The maximum increase in water surface elevation along a levee was modeled to be 0.12 ft.
- The water surface remains well below the design profile: 0.5 to 1.5 feet below the design profile in the immediate vicinity of the project (see **Figure 8**). **Figure 10** indicates that the minimum difference between the design profile and the restored conditions (with project) water surface elevation at the cross-section in the affected area is 0.86 ft.

Velocity

Model Results

- Model results point to four areas that could be of concern under existing conditions (without project), depending on levee armoring at those sites. (See **Figure 12**).
    - The model indicates that under existing conditions, when 160,000 cfs enters the Colusa Subreach, there are three locations adjacent to levees where velocities approaching or exceeding 5 ft/sec would occur. Locations 1 and 2 are located at the north and south edges of the entry to Colusa Bypass. Maximum modeled velocities there are between 8 and 10 ft/sec, in the range where armoring would likely be required for bank stability. Location 3 is at Cruise 'n Tarry. The maximum modeled velocity at Location 3 is 4.74 ft/sec, just below the 5 ft/sec threshold below which banks tend to be stable if well-vegetated.
    - Under existing conditions, where the main channel curves toward the fourth location, along the East bank at river mile 144.6, velocities of up to 3.50 ft/sec occur in the center of the channel. The maximum velocity of 3.50 ft/sec occurs 230 ft out from the levee bank.
- Net changes in velocity modeled to occur if the project is implemented are shown in **Figure 13**. The difference between existing conditions and restored conditions (with project) modeled velocity distributions is sometimes positive, and sometimes negative. In other words, the graphic depicts show some increases in velocity (shown in warm colors) and some decreases in velocity (shown in cool colors).
- Some velocity increases shown in **Figure 13** occur where, given the original, existing condition velocities shown in **Figure 12**, they are not significant.
    - Three of the areas of velocity increase shown in **Figure 13** occur where original, existing condition velocities are low. There are two areas along the western levee (note the 0.37 ft/sec and 0.78 ft/sec call outs in **Figure 13**). The third occurs in the "overbank flow corridor" of low hydraulic roughness vegetation (grass and savannah) that runs through the center of Ward Tract in the proposed restored condition.
    - Velocity increases also are shown in **Figure 13** in the main channel for approximately two river miles adjacent to and downstream of Ward Tract. The maximum velocity increase is called out, at 1.04 ft/sec, across from the entrance to Colusa Bypass.

- Velocity increases at the four sites where there is potential for concern under existing conditions (without project), depending on levee armoring, are also called out in **Figure 13**:
    - Location 1, along northern levee at entry of Colusa Bypass: 0.10 ft/sec increase (maximum velocity increase of 0.21 occurs at a distance from the levee in this general area)
    - Location 2, along southern levee at entry of Colusa Bypass: 0.13 ft/sec increase
    - Location 3, Cruise ‘n Tarry: 0.14 ft/sec increase
    - Location 4, main channel at river mile 144.6: 0.24 ft/sec increase
- The areas of greatest reduction in velocity are concentrated within the Ward Tract. (See **Figure 13**). The resultant velocities under restored conditions (with project) are shown in **Figure 14**. In side by side comparison of **Figure 14** with **Figure 12**, what stands out most is the increase in in-channel velocities.
- Resultant maximum velocities maxima at the four sites where there is existing potential for concern are called out in **Figure 14**:
    - Location 1, along northern levee at entry of Colusa Bypass: 9.71 ft/sec
    - Location 2, along southern levee at entry of Colusa Bypass: 8.64 ft/sec
    - Location 3, Cruise ‘n Tarry: 4.74 ft/sec
    - Location 4, main channel near levee at river mile 144.6: 3.74 ft/sec 230 ft from levee.
- Please note also that the velocity results contain no comparison to design conditions because there are no design velocity conditions.

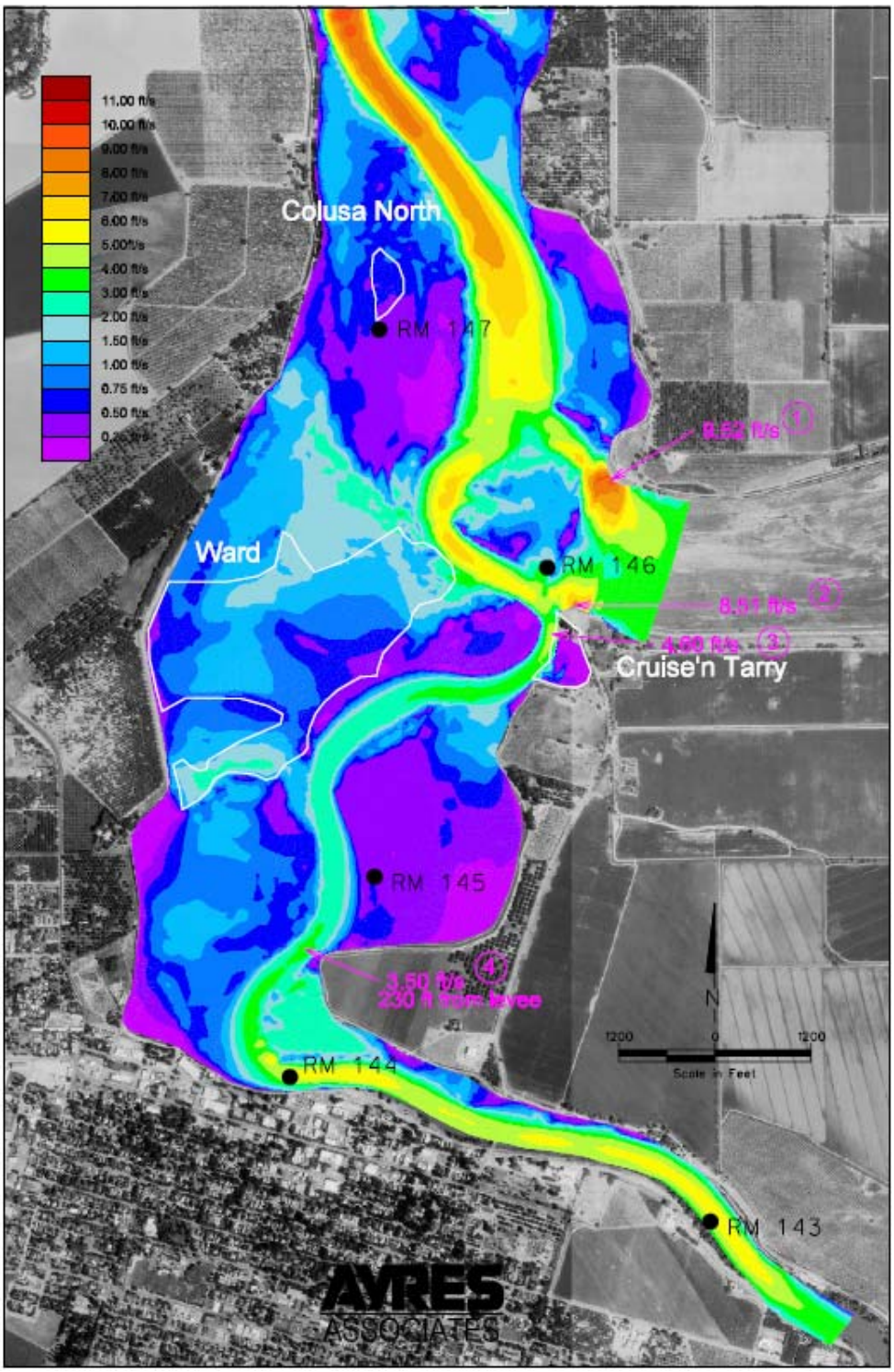


Figure 12: Modeled Existing Conditions (Without Project) velocity distribution (Ayres Associates)

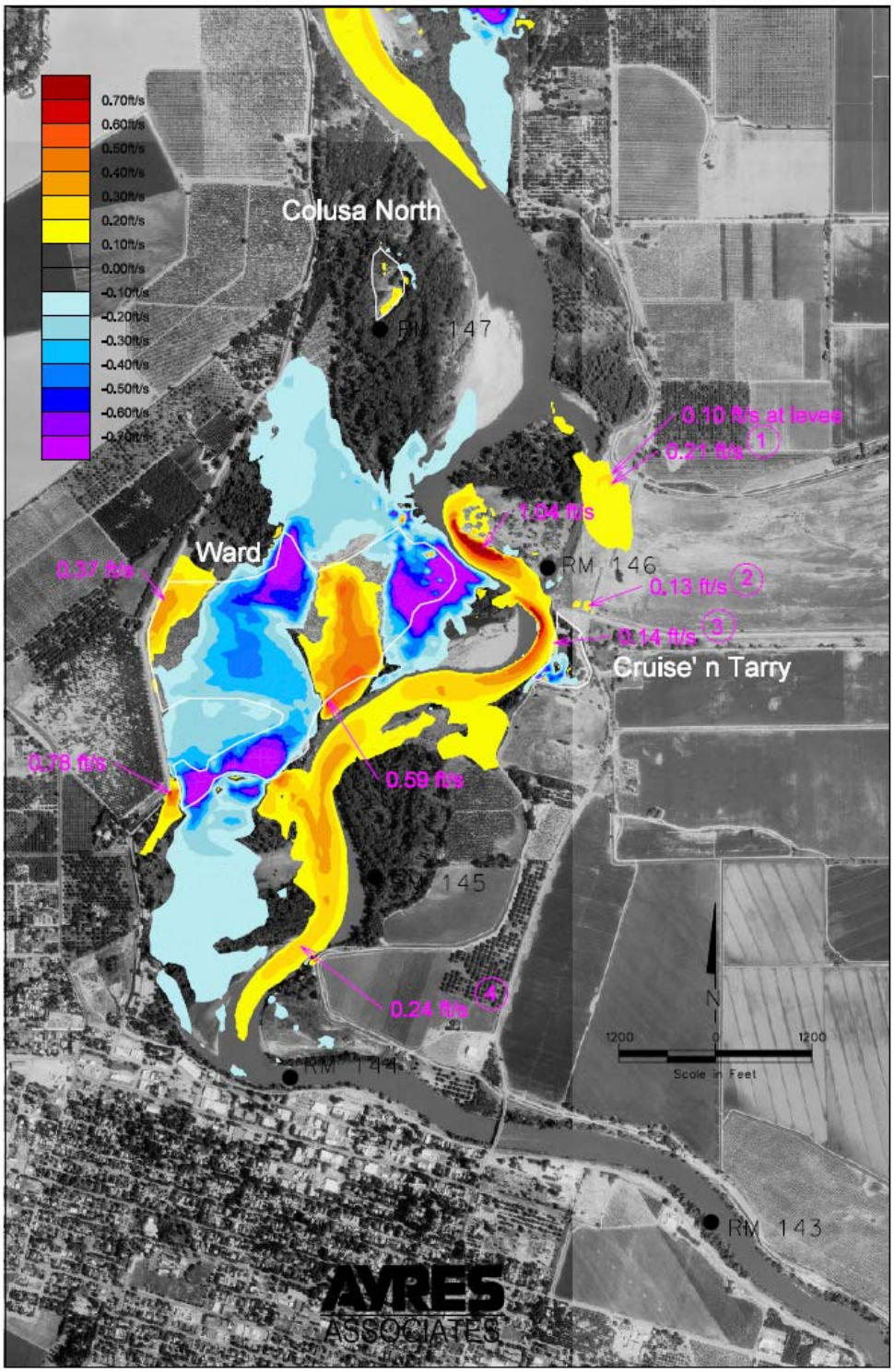


Figure 13: Net changes in velocity; Difference between modeled Existing Conditions (Without Project) and Restored Conditions (With Project) velocity distributions (Ayres Associates)

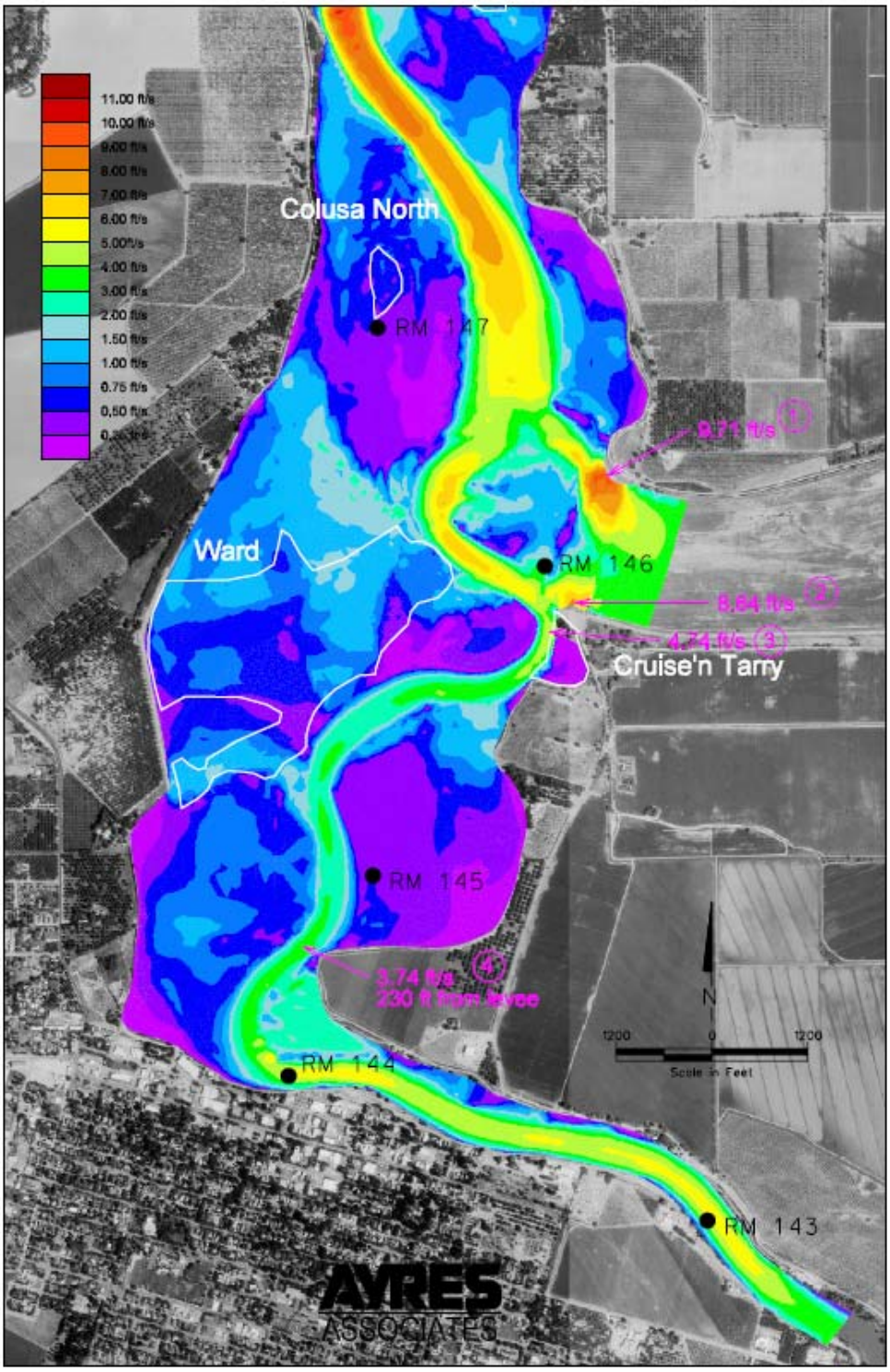


Figure 14: Restored Conditions (With Project) modeled velocity distribution (Ayres Associates)

Interpretation

- Model results point to four areas that could be of concern under existing conditions (without project), depending on levee armoring at those sites.
- At these four areas of potential concern, DWR field-checked levee conditions. Site inspection revealed that all four sites have armoring sufficient to withstand the projected existing velocities:
    - The rock revetments at locations 1 and 2 are partially buried in finer sediment. Field staff indicate material has accumulated atop the cobble and blasted rock. There is no sign of deterioration. (See **Figure 15** and **Figure 16**). An additional factor of safety exists at locations 1 and 2 because where high velocities are modeled to occur, the land immediately behind the levees is filled to approximately the same elevation as the levee tops, creating parking lots that effectively increase the width of the levees at these places.
    - DWR has recognized the erosion activity at location 3. There is rock revetment along the northern portion, and DWR has already built a set-back levee along the southern portion of Cruise 'n Tarry because the main channel is active against that bank. (See **Figure 17** and **Figure 18**).
    - At location 4, the velocity increase of 0.24 ft/sec modeled to occur due to restoration is focused in the main channel, resulting in a maximum velocity of 3.74 ft/sec approximately 230 ft from the toe of the levee during the modeled flow conditions. While it is true that if the main channel migrates eastward, erosive force on the levee will increase, this potential condition would be the result of fluvial process in the river at large, rather than the proposed restoration at Ward Tract. In any case, the blasted rock revetment of the levee should well withstand potential velocities in the 4 ft/sec range if the river channel does shift eastward, as well as the velocities of up to 0.75 ft/sec projected to occur near the levee tip with the existing river alignment. (See **Figure 19 and Figure 20**).
    - For more detail on the site inspection, see **Appendix D. Appendix D** contains a memo and photographs summarizing the results of the site visits made on November 20, at which the erosion potential of all four locations of potential concern was evaluated.
- Modeling results indicate that the restoration project would increase velocities by 0.1 to 0.14 ft/sec near levees at locations 1, 2, and 3, and 0.24 ft/sec at location 4. (See **Figure 13**). These are relatively small velocity increases. Just as all four locations are competent to withstand the projected existing conditions (without project) velocities under the modeled scenario, they are competent to withstand the increased velocities under restored conditions (with project).

- Acceleration across the overbank flow corridor (the area to be planted with grass and oak savannah) across Ward Tract is desirable, as it is a feature that limits the hydraulic effects of the project. Because the acceleration is focused in a low velocity area, no erosion is expected to develop in the overbank flow corridor.
- Acceleration within the main channel is also shown. The pattern of acceleration, coupled with the existing velocities along those bends, tends to suggest an incremental increase in erosion of sandbars that have formed may occur. This is especially true of the sandbar located opposite the entrance to Colusa Bypass. Reworking of this sandbar is seen as desirable from a flood management perspective. No appreciable change to the sand bar on the Ward Tract would be expected based on the model results.
- Because the areas of greatest reduction in velocity are concentrated within the Ward Tract, (see **Figure 13**), new tendency toward deposition is also concentrated within the Ward Tract property. Recall that the Ward Tract property is somewhat larger than the Ward restoration outlined in the modeling graphics (see **Figure 2**).

Figure 15: Location 1, Northern bank along entrance to Colusa Bypass

Figure 16: Location 2, Southern bank along entrance to Colusa Bypass

Figure 17: Location 3, Bank of Cruise and Tarry

Figure 18: Location 3, Original Levee & Setback Levee at Cruise and Tarry

Figure 19: Location 4, Rock Revetment and Mature Vegetation

Figure 20: Location 4, Transition of Underlying Rock Revetment to top surface of soil and vegetation

Conclusion

DWR found Ayres' model to offer an acceptable representation of the Colusa Subreach.

The results of the model indicated minor stage, flow and velocity changes from existing conditions (without project) to restored conditions (with project). The projected restored condition (with project) water surface elevation is well below the design profile. In addition, the two dimensional water surface elevation changes calculated by the model are small. Flow changes detected are within the limits of input data reliability.

Four locations where modeling indicated erosion might be of concern due to high velocities under existing conditions (without project) were evaluated in the field. Examination of these field conditions indicated that levee conditions are competent to withstand the projected existing condition (without project) and restored condition (with project) velocities. Potential for additional erosion or deposition on the floodplain due to velocity changes is concentrated on the Ward Tract property.

We find that the proposed restoration project at Ward Tract would not compromise the Flood Control System nor adversely affect neighboring properties.

References

Ayres Associates. February 2, 2007. Draft Initial Report: Two-Dimensional Hydraulic Modeling of Riparian Habitat Restoration from Colusa to Princeton, Sacramento River, RM 142.5 to 164.5, Glenn and Colusa Counties, CA

Ayres Associates. (Draft - In press). Two-Dimensional Hydraulic Modeling of Riparian Habitat Restoration from Colusa to Princeton, Sacramento River, RM 142.5 to 164.5, Glenn and Colusa Counties, CA

Appendix A:
Land Use Type Photo Documentation Appropriateness at Sites

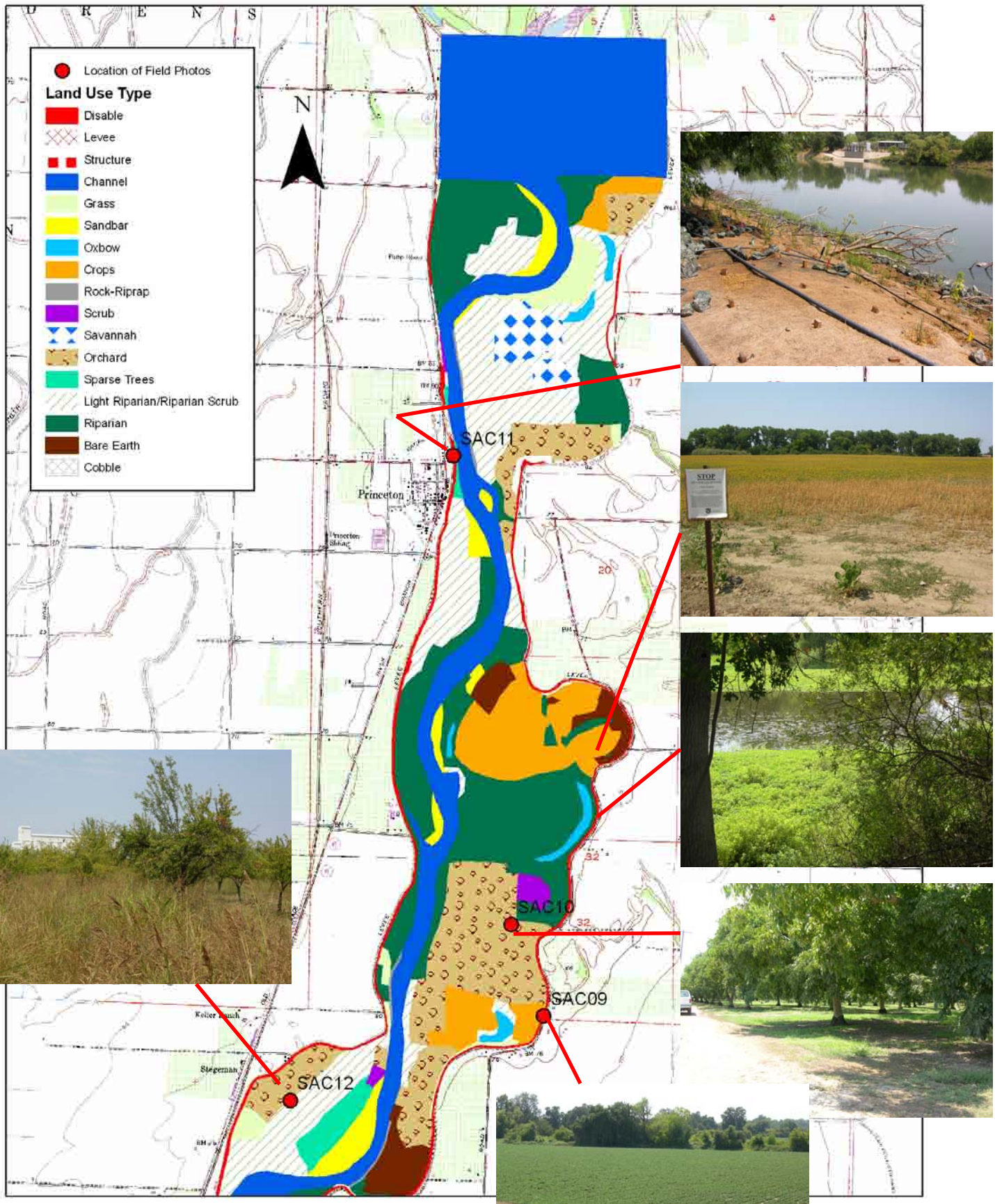
Appendix A illustrates the modeled land use types and photographs of associated land use at several sites. Due to scaling issues, some smaller sized patches of a given land use (i.e. thin strips along levees) might not be visible on the maps. Overall, the results of the field visit showed that the majority of sites closely matched the categories used by Ayres.

- Two of the sites, labeled SAC11 and SAC16, are sites that have been restored recently, with newly planted trees and newly constructed irrigation systems. The land use that Ayres used in the model for the two sites was sparse trees and scrub, respectively. Conditions at these sites may grow into riparian habitat, but in order to achieve calibration to existing conditions, Ayres needed to represent these existing conditions.

- At the time of the field visit SAC17 looked as though riparian might have been a more appropriate category than the categories used, light riparian and sparse trees. However, the Ayres designation still seems reasonable, especially considering the land use was determined from aerial photographs, and the DWR site visit was performed during the summertime, when vegetation is more leafy than during the flood season.

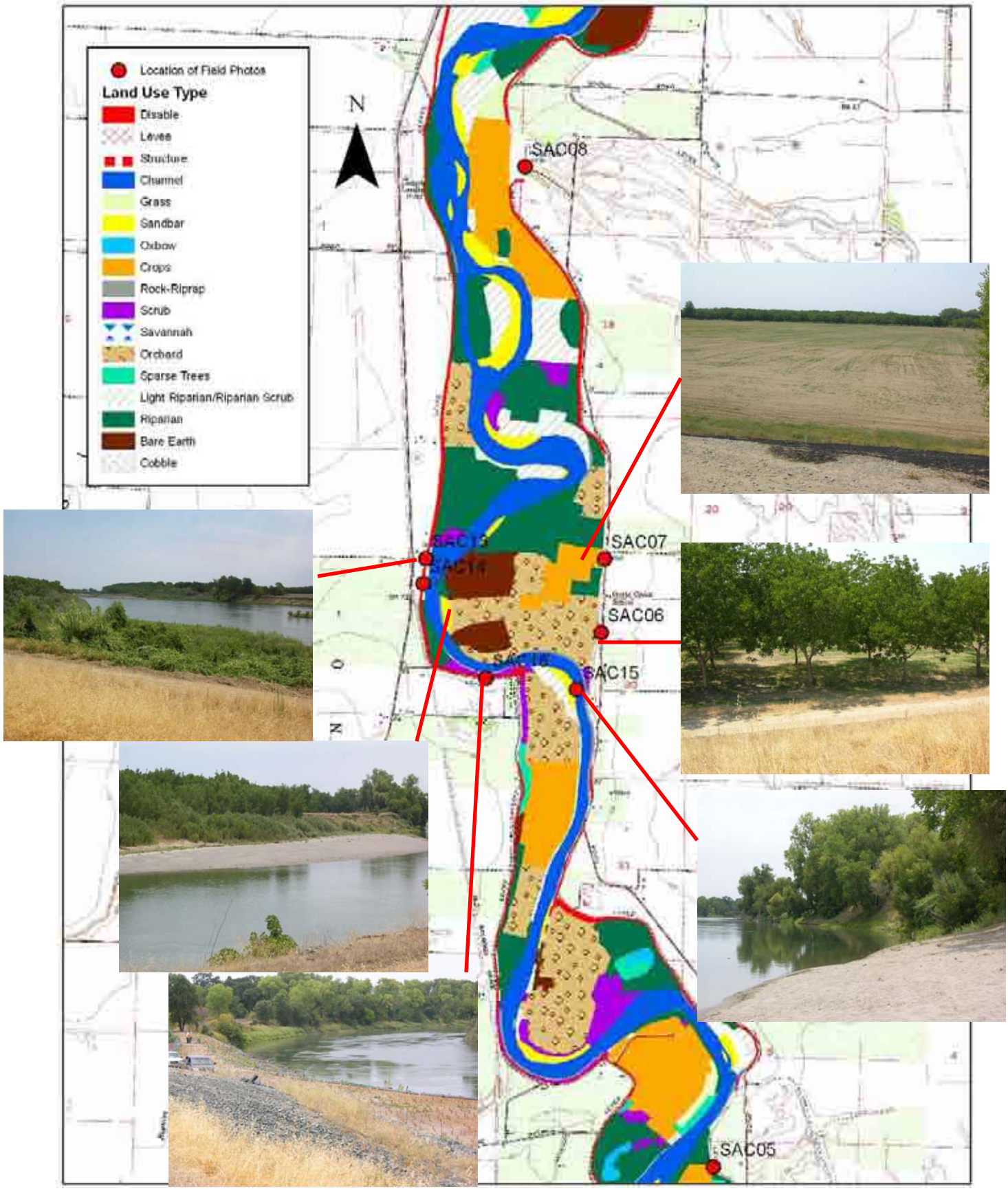
- While in the field, DES staff attempted to visit all 8 possible restoration sites as listed in the Ayres Draft Initial Report. All sites were visited except for the Colusa North Site, which is currently only accessible via boat access. DWR found that all field sites visited other than SAC 17 closely matched those that were used by Ayres.

Appendix A: ARPI Field Photos (July 2007) and Ayres Land Use Types for the Sacramento River Colusa Subreach

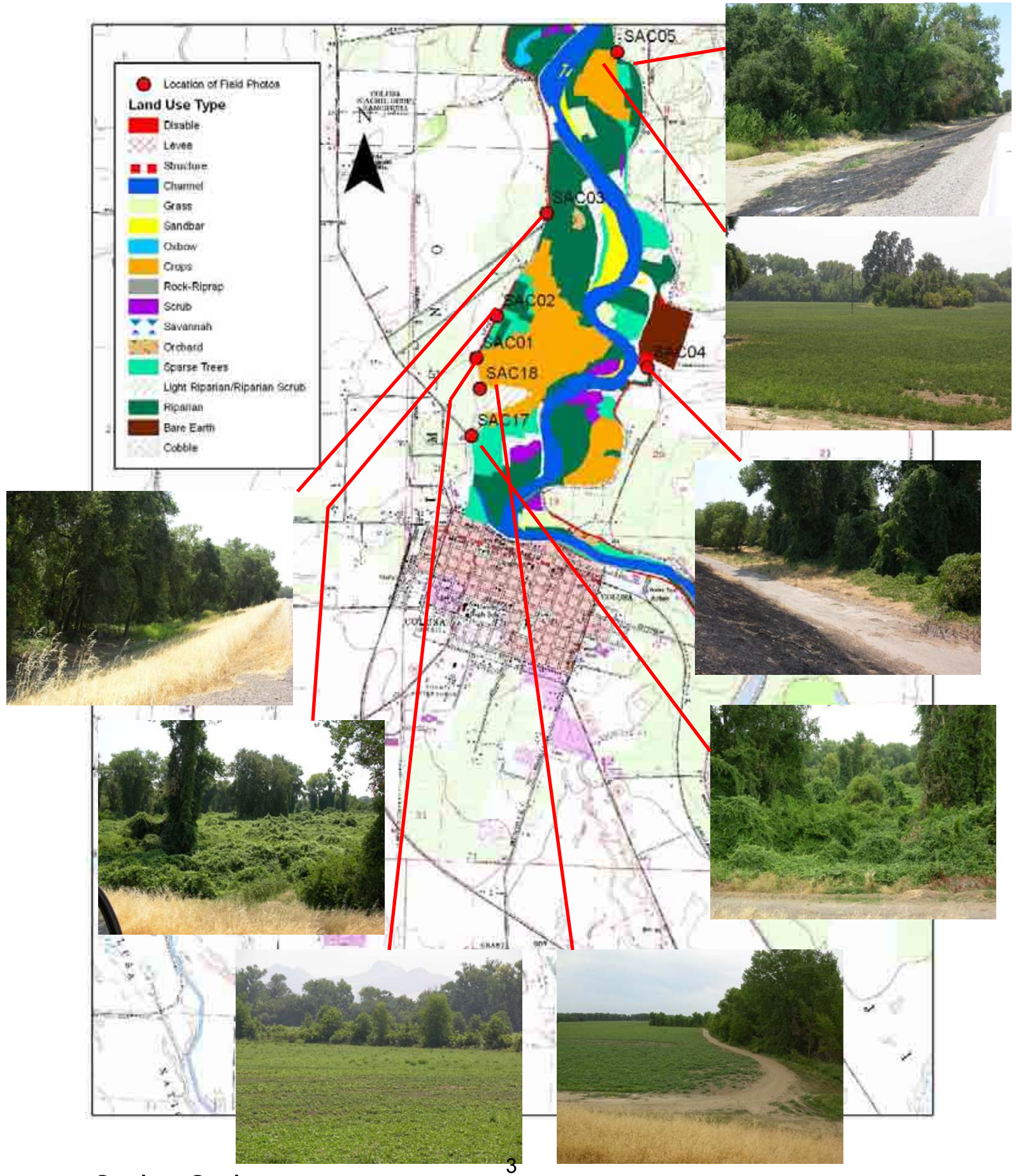


Northern Section

Appendix A: ARPI Field Photos (July 2007) and Ayres Land Use Types for the Sacramento River Colusa Subreach



Appendix A: ARPI Field Photos (July 2007) and Ayres Land Use Types for the Sacramento River Colusa Subreach



Southern Section

Appendix B
Land Use Type Photo Documentation
Consistency Among Types

In Appendix B, a direct comparison of multiple locations with the same land use designation is displayed, to offer a sense of the similarity and variability of a given land use designation. One can see that examples of crops, orchard, and sand bar appear quite similar within each individual category, while light riparian, riparian, and sparse trees showed more variation between sites for a given land use type designation.

Examples of Crop Land Use in Colusa Subreach

Ward Tract 7-9-07

Boeger Tract 7-9-07

West of River Road and North of Butte Creek School 7-9-07

West of River Road and North of Gridley Road 7-9-07

Womble Tract 7-9-07

Examples of Orchard Land Use in Colusa Subreach

West of River Road and South of Butte Creek School 7-9-07

West of River Road and North of Gridley Road Tract 7-9-07

Jensen Tract 7-9-07

1000 Acre Ranch Tract 7-10-07

Examples of Sandbar Land Use in Colusa Subreach

East Bank North of Reservation Road 7-10-07

West Bank Colusa Rancheria 7-10-07

Examples of Light Riparian/Riparian Scrub Land Use in Colusa Subreach

West Bank Colusa Rancheria 7-10-07

Trail into Stegeman Tract 7-18-07

East Bank at Princeton 7-18-07

West Bank South of Princeton at Paradise Road 7-18-07

Examples of Spare Trees Land Use in Colusa Subreach

Sabin Lake North of Ward Tract 7-9-07

South of Ward Tract 7-10-07

Princeton 7-18-07

Example of Grass Land Use in Colusa Subreach

West Bank Colusa Rancheria 7-10-07

Example of Oxbow Land Use in Colusa Subreach

Womble Tract 7-9-07

Appendix C
Range of Hydraulic Roughness Coefficients

The appropriateness of Manning's 'n' roughness coefficients used in the model was placed in context by reviewing hydraulics literature. Five sources were used for comparison. Overall, the values were reasonable. Appendix C contains a table summarizing the literature review results.

One issue that arose when comparing the Manning's coefficients was that while several sources were used to obtain a better understanding of the range of values for each type, verbal descriptors were seldom consistent between sources. Several of the material types (sandbar, levee, oxbow, orchard, and structure) that Ayres used were unusual and were not specifically found in any of the literature, though sandbar, levee, oxbow and orchard values appear to be reasonable when compared to seemingly similar material types. There was no material type similar to the "structure" classification.

Manning's n Roughness Coefficients from Literature Review											
Used by Ayres Associates		According to: Fluid Mechanics (White)		CERM (Lindeburg)		Website (from Chow, 1959)*		Hyrdology and Floodplain Analysis (Bedient, Huber)		Hydraulic Engineering (Roberson, Cassidy, Chaudhry)	
Material	n	Material	n	Material	n	Material	n	Material	n	Material	n
Smooth Concrete	0.014	Cement, finished	0.012	Concrete, avg	0.013	Concrete, trowel finish	0.013	Concrete, float finish	0.015	Concrete, troweled	0.012
Sandbar[1]	0.02										
Channel	0.025	Natural Channel - major river	0.035	Natural channel, good cond.	0.025	Main channel, clean, winding, some pools and shoals	0.040	Natural Stream, clean, winding, some pools and shoals	0.040	Natural Channels, Earth, straight, with some grass	0.026
Levee[2]	0.03										
Bare Earth	0.03			Smooth earth	0.018					Bare ground	0.030
Grass	0.032	Excavated earth channel - weedy	0.030	Natural channel, with stones and weeds	0.035	Pasture, short grass	0.030	Floodplain - pasture, no brush, high grass	0.035	Grassland - tall grass	0.035
Oxbow[3]	0.035										
Crops	0.035	Pasture, farmland	0.035			Mature row crops	0.035			Mature row crops	0.035
Scrub	0.04					Floodplain, scattered brush, heavy weeds	0.050	Brush, Scattered brush, heavy weeds	0.050	Dense weeds and sparse brush	0.050
Cobble	0.04	Excavated earth channel- Stony, cobbles	0.035			Dredged channels, cobble bottom and clean sides	0.040	Mountain stream steepbanks; gravel and cobbles	0.040		
Rock Riprap	0.045			Riprap	0.035						
Savannah	0.045	Floodplain, light brush	0.050			Light brush and trees, winter	0.050	Brush, Scattered brush, heavy weeds	0.050	Brush-covered with some trees (winter)	0.050
Sparse Trees	0.06					Light brush and trees, winter	0.050			Brush-covered with some trees (winter)	0.050
Light Riparian / Riparian Scrub	0.07					Medium to dense brush, winter	0.070			Dense Brush (winter)	0.070
Orchard[4]	0.075										
Riparian Forest	0.09					Floodplain, trees-heavy stand of timber	0.100	Trees, heavy stand of timber	0.100	Dense stands of large trees, flood stage below branches	0.100
Structure[5]	0.2										

* http://www.fsl.orst.edu/geowater/FX3/help/8_Hydraulic_Reference/Mannings_n_Tables.htm

1. Sandbar - No obvious comparison found. 0.02 seems reasonable but may be a little low (i.e. it's less than excavated earth channel, clean, 0.022, White)
2. Levee - No obvious comparison found. 0.03 seems reasonable since it is similar to bare earth and grass.
3. Oxbow - No obvious comparison found. 0.035 seems reasonable. Possibly similar to Earth winding and sluggish - dense weeds or aquatic plants in deep channels 0.035 (website, Chow 1959)
4. Orchard - No obvious comparison found. 0.075 seems reasonable. For trees - heavy stand of timber, a few down trees, little undergrowth, flood stage below branches 0.1 (website, Chow 1959)
5. Structure - could not find a Manning's n in any source for "structure"

Appendix D
Site Visit to Evaluate Erosion Potential near Colusa Mitigation Area

Three locations of potential existing concern, due to high modeled velocities, were initially identified and investigated by DWR staff. Identification of a fourth location of potential concern arose from the Colusa Subreach Planning meeting held in Colusa County November 15. Appendix D contains a memo and photographs summarizing the results of the site visits made on November 20, at which the erosion potential of all four locations of potential concern was evaluated.

OFFICE MEMO

TO: File	**DATE:** November 26, 2007
FROM: Chris Jones	**SUBJECT:** Site visit to evaluate erosion potential near Colusa Mitigation Area

On November 20, 2007, DWR staff performed a field review of four locations near the proposed Colusa SRA Mitigation Site to evaluate erosion potential under high Sacramento River flows. The field review team included Chris Jones and Mike Engelmann of the DFM/FMO Maintenance Support Branch, Karen Hull and Joel Farias of the DFM/FMO Sutter Maintenance Yard, and Marianne Kirkland of the Division of Environmental Services (DES). This field review was performed in response to concerns raised about increased flow velocities shown in a hydraulic model of the area. The model depicts high flow conditions with inclusion of riparian forest and related features associated with a proposed environmental mitigation project near the Colusa State Recreation Area. The proposed mitigation would address environmental impacts of the recently completed Tisdale Bypass Sediment Removal Project, and include mitigation planting on about 135 acres of land within the floodway.

The four locations are referred to herein as Locations 1, 2, 3, and 4 (See Figure 1). All locations were recorded in longitude/latitude using a hand-held GPS using the WGS84 datum. Location 1 is at approximate latitude N39°14.2' and longitude W121°59.7', which is adjacent to the levee at the north end of the Colusa Weir. Location 2 is at approximate latitude N39°13.9' and longitude W121°59.8', which is adjacent to the levee at the south end of the Colusa Weir. Location 3 is at approximate latitude N39°13.8' and longitude W121°59.9', which is on the left bank of the Sacramento River and Marianne indicated that locals refer to as "Cruise 'n Tarry". Location 4 is at approximate latitude N39°13.2' and longitude W122°0.5', which is on the left bank of the Sacramento River just upstream of the town of Colusa. Figure 1 also shows the locations and directions of Photos 1 through 9, documenting the inspection.

Locations 1 and 2 consist of the North and South levees immediately upstream of the Colusa Weir. Each of these locations contains revetment consisting of cobbles covered with soil. In addition, the buried South levee revetment (Location 2) contains blasted rock. Sutter Maintenance Yard personnel have not observed erosion at these locations in the past. Because of the lack of historical erosion issues at these locations and the presence of revetment, these sites were determined to be safe from potential erosion due to the small flow velocity increases modeled to result from the proposed mitigation project.

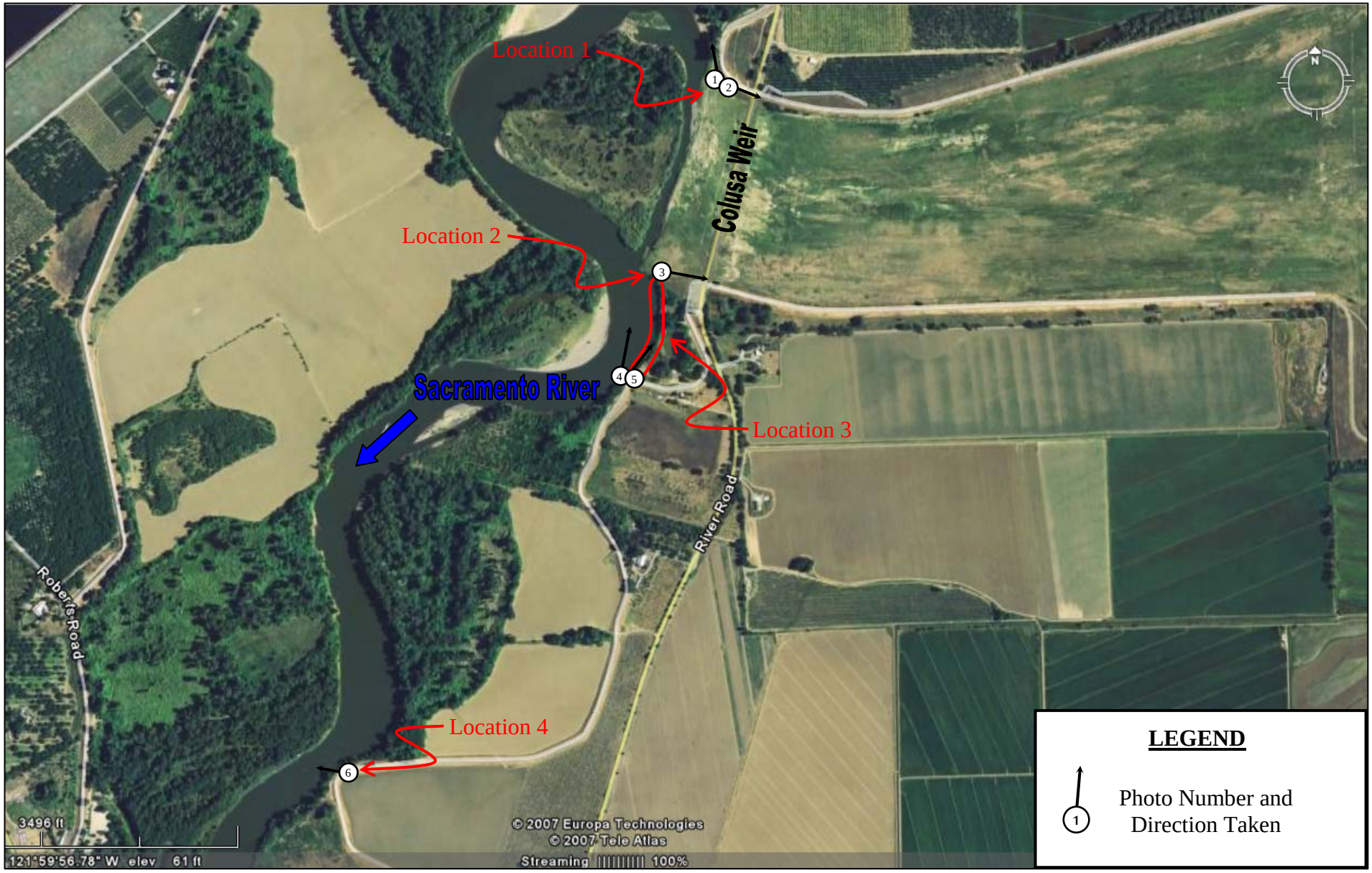
Location 3 is protected by rock revetment within its upstream segment and by a setback levee at its downstream segment. Therefore, the upstream segment of the site is protected from erosion. The downstream segment may be subject to some bank recession, however, approximately 100 feet or more separate the bank from the setback levee, and therefore this segment is not in danger of losing flood protection.

Location 4 was evaluated in response to concerns raised by Ben Carter of the Reclamation Board due to the increased flow velocities that were modeled around the river bend near that location. The site was observed in the field to be covered with blasted rock revetment along its entire extent to within at least 10 feet of the levee crest. Mature vegetation exists on the slope and no erosion features were observed. Sutter Maintenance Yard personnel have not observed any problems at this location. Because of the lack of historical erosion issues at this location and the presence of revetment, Location 4 was determined to be safe from potential erosion due to the small flow velocity increases modeled to result from the proposed mitigation project.

Photos 1-9 show:

1. Levee at Location 1 (looking NW)
2. Levee at Location 1 (looking SE)
3. Levee at Location 2 (looking W)
4. Levee at Location 2 (looking E)
5. Location 3 (looking N)
6. Location 3 (looking NE)
7. Levee at Location 4 (looking downslope and W)
8. Toe of Levee at Location 4 (looking NE)
9. Toe of Levee at Location 4 (looking SW)

The overall result of the field review is that none of the 4 observed locations is considered to be an erosion hazard due to the small increased flow velocities resulting from the proposed mitigation project.



DEPARTMENT OF WATER RESOURCES
Division of Flood Management
Office of Flood Maintenance
System Integrity Section A

IO: F0423SI08302

Date: November 2007

PHOTO LOCATION MAP

Figure 1

EROSION EVALUATION NEAR COLUSA MITIGATION AREA

DEPARTMENT OF WATER RESOURCES
Division of Flood Management
Office of Flood Maintenance
System Integrity Section A

IO: F0423SI08302

Date: November 2007

Levee at Location 1 (looking NW)

Photo 1

EROSION EVALUATION NEAR COLUSA MITIGATION AREA

DEPARTMENT OF WATER RESOURCES
Division of Flood Management
Office of Flood Maintenance
System Integrity Section A

IO: F0423SI08302

Date: November 2007

Levee at Location 1 (looking SE)

Photo 2

EROSION EVALUATION NEAR COLUSA MITIGATION AREA

DEPARTMENT OF WATER RESOURCES
Division of Flood Management
Office of Flood Maintenance
System Integrity Section A

IO: F0423SI08302

Date: November 2007

Levee at Location 2 (looking W)

Photo 3

EROSION EVALUATION NEAR COLUSA MITIGATION AREA

DEPARTMENT OF WATER RESOURCES
Division of Flood Management
Office of Flood Maintenance
System Integrity Section A

IO: F0423SI08302

Date: November 2007

Levee at Location 2 (looking E)

Photo 4

EROSION EVALUATION NEAR COLUSA MITIGATION AREA

DEPARTMENT OF WATER RESOURCES
Division of Flood Management
Office of Flood Maintenance
System Integrity Section A

IO: F0423SI08302

Date: November 2007

Location 3 (looking N)

Photo 5

EROSION EVALUATION NEAR COLUSA MITIGATION AREA

DEPARTMENT OF WATER RESOURCES
Division of Flood Management
Office of Flood Maintenance
System Integrity Section A

IO: F0423SI08302

Date: November 2007

Location 3 (looking NE)

Photo 6

EROSION EVALUATION NEAR COLUSA MITIGATION AREA

DEPARTMENT OF WATER RESOURCES
Division of Flood Management
Office of Flood Maintenance
System Integrity Section A

IO: F0423SI08302

Date: November 2007

Levee at Location 4 (looking downslope and W)

Photo 7

EROSION EVALUATION NEAR COLUSA MITIGATION AREA

DEPARTMENT OF WATER RESOURCES
Division of Flood Management
Office of Flood Maintenance
System Integrity Section A

IO: F0423SI08302

Date: November 2007

Toe of Levee at Location 4 (looking NE)

Photo 8

EROSION EVALUATION NEAR COLUSA MITIGATION AREA

DEPARTMENT OF WATER RESOURCES
Division of Flood Management
Office of Flood Maintenance
System Integrity Section A

IO: F0423SI08302

Date: November 2007

Toe of Levee at Location 4 (looking SW)

Photo 9

EROSION EVALUATION NEAR COLUSA MITIGATION AREA